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CRITIQUE AND PROPOSAL FOR
THE MANAGEMENT OF DREDGED MATERIAL
IN MASSACHUSETTS BAY WATERS

PART 1

SR-58

<u>Final Report</u>

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PREFACE

Part 1 of Contract No. DACW33-76-C-0096 summarizes and critiques U.S. Army Corps of Engineers, New England Division, reports of five dumpsites along the New England coast. Part 2 of the report summarizes bioassay experiments of materials from the sites and critiques the proposed bioassay procedures.

Studies of dredge material disposal were made in dumpsites in Long Island Sound, Rhode Island Sound, Block Island, Buzzards Bay, Maine and New Hampshire, Boston Harbor and Massachusetts Bay, under contract with the New England Division, U.S. Army Corps of Engineers (Appendix A). The analyses are site specific. The results show little "environmental damage" and biological recolonization of the dumpsites occurs within months.

Management of Disposal Sites

The impact of disposal materials on a disposal site may be determined by an intensive monitoring program which would include physical, chemical and biological parameters, or if baseline data are available, by a limited seasonal monitoring program which is directed toward benthic identification and recolonization. In the laboratory, a bioaccumulation bioassay can evaluate nutrient cycling, energy transfer and concentration factors of metals and xenobiotics in benthic populations. The impact of dredge spoil disposal on fisheries, including spawning and breeding areas and on shellfish beds, should be determined.

Where disposal sites have already been studied, limited monitoring is sufficient. In the selection of a new disposal area or a regional disposal area, an intensive monitoring program is needed to characterize the site with respect to its suitability for the acceptance of dredge spoil materials.

In the laboratory, bioaccumulation experiments are a way to evaluate impact of materials at the sublethal level. In the field, burial of benthic organisms is followed by recolonization, but the studies have not assessed sublethal effects on benthic populations (see Part 2 of this report).

Site Selection for Ocean Dumping in Massachusetts Bay

Prior to 1971 there were two sites in Massachusetts Bay for dredged spoil dumping. The Boston Lightship was used for clean dredged materials and the Massachusetts Bay Foul Area received polluted dredged spoil.

In 1977 the Environmental Protection Agency designated the old Massachusetts Bay Foul Area for disposal of hazardous wastes for Region I. In addition, an overlapping circle 1° to the east was designated the Marblehead disposal site for dredged spoil. This was an interim regulation for a period of three years. In January 1980, EPA terminated the hazardous waste site and extended the Marblehead site for another three years. The Boston Lightship site has been closed to dumping.

If the revised EPA Ocean Dumping Regulations of 11 January 1977 are met, one must assume that spoil is relatively clean and that there will be no significant ecological change in the disposal area. The EPA suggests there may be cases where polluted spoil will need to be disposed of due to practical economic considerations. A problem with the EPA regulations is that there are few studies which will unequivocally show that concentrations of listed materials have an acute or sublethal effect on benthic organisms. The state regulatory agencies differentiate between dirty and clean spoils on a case-by-case basis, but with no clear definition of either. Finally, the dumping of the spoil may be regulated by EPA, State of Massachusetts, Corps of Engineers, and Food and Drug Administration. Interestingly enough, the last agency can close potential dumpsites if they determine there is potential harm to bottom dwellers.

ABSTRACT

The objective of this report is twofold. First, to critique studies conducted for the U.S. Army Corps of Engineers of dump sites located in Long Island Sound, Rhode Island Sound, Block Island, Buzzards Bay, Maine, New Hampshire, Boston Harbor, and Massachusetts Bay. Second, to develop criteria of a management plan for regional dumping.

Criteria for disposal management in Massachusetts Bay include site selection, characterization of the dredge site and disposal site environments, loading rates, disposal site capacity, criteria for disposal and monitoring programs for evaluation of possible changes in the disposal site environment. The site of choice for disposal of dredged material in Massachusetts Bay is the Marblehead Site for Dredged Material when using the E.P.A. Criteria for Ocean Dumping as the acceptable limit for disposal of toxic substances (EPA, 1980). In the laboratory, a bioaccumulation bioassay can evaluate the impact of spoil materials at sublethal levels. In the field, measurement of recolonization can assess environmental impact of regional dumping.

CRITIQUE AND PROPOSAL FOR THE MANAGEMENT OF DREDGED MATERIAL IN MASSACHUSETTS BAY WATERS

INTRODUCTION

Dredging operations in New England have been for the purpose of maintaining navigable waterways for commercial and recreational use. The material is the result of natural siltation from rivers and streams, and discharged waste materials of an industrial society. Disposal of the dredge spoil is a stress to the environment, especially if xenobiotics are introduced.

The New England Division of the Army Corps of Engineers has sponsored studies relating to ocean disposal and the impact of dredged materials on an ocean environment. These studies evaluated a) turbidity effects on plankton and epifauna, b) organism burial and recovery, c) nutrient enhancement or depletion, d) trace metal turnover, and e) the direct and indirect long-term effects on the benthos (Appendix A).

To establish ocean dumping criteria, it is necessary to determine the characteristics of potential spoils, the suitability of the disposal site to the effects of dredge spoil, and to define a management program for the disposal site. An extensive data base derived from many disposal areas can give a reasonable picture of the environmental problems involved only if the analyses are comparable between the various areas studied. In many cases, parameters measured in one area were not measured in another. Also, improvements in technology have allowed more accurate measurements which can show subtle changes in environmental quality reflecting long-term ecological effects. Standardization of the best analytical methodology available and periodic updating of methodology will help to produce more reasonable and effective programs for disposal site management. A management program must consider the effects of spoil loading on the benthos and epifauna of the disposal site surroundings, the potential biochemical effects of the spoil on these organisms, and potential movement of the spoil due to topography, material type, and current patterns of the area.

Physical analyses measure the amount of suspended solids in the water column as a result of dredging and disposal operations. Studies by Saila, et al. (1969)(SR-1) show that lobsters subjected to high concentrations of suspended material have difficulty clearing their gills. Research by Stone (1974) (SR-36) on turbidity effects on scallops and mahogany quahogs indicates that the animals expend considerable energy in clearing the gills and that their feeding ability is inhibited due to the increased ratio of suspended solids/food supply.

Analysis of a disposal operation by Gordon, et al. (1972) (SR-7) showed that approximately 90% of a spoil dump in Long Island Sound went directly to the bottom in a density current and that the remaining fines fell as individual particles. Less than 1% of the material remained suspended in the water column. The effect of turbidity on biota in this sort of dumping operation would be minimal, since both Saila, et al., and Stone showed that animals recovered following removal from high turbidity.

Chemical analysis of the dredge site area measures possible pollutants. These analyses may be omitted if the dredge material is all coarse sand and gravel. Finer-grained sediments chemical analyses include testing for oil and grease, PCB's, bacteria, H_2S, metals (e.g. Zn, Cu, Cd, Pb, Hg, V, Ni, As or others, depending on historical input to the area), and nutrient compounds: nitrate, phosphate, and ammonia concentrations. The possibility of any of these constituents being released into the water column must be measured, as well as their availability to benthic and epibenthic organisms. For example, the bioavailability of metals bound up in the crystalline lattice of fine sand or silt particles may be minimal, but metals sorbed on detrital material may be released to the water column or ingested and concentrated by filter feeding and deposit feeding benthic fauna.

The release of pollutants from the dredged material has usually been measured with the elutriate test, developed jointly by the EPA and the Army Corps of Engineers (Federal Register, 1973). By agitating the spoil material with water from the dredge site or the disposal site, one may obtain an estimate of the pollutant levels likely to be released. A limit of concentration of 1.5 times the ambient concentration was set as a guideline.

In the elutriate test, 1 part of spoil materials is suspended in 4 parts water, a ratio that simulates the makeup of the slurry generated during hydraulic dredging. Lee, et al. (1975) suggested the use of a 5% suspension of spoil in water. This smaller ratio reduced the time necessary to obtain a sufficient volume of elutriate for analysis. The 5% suspension is more closely related to the mechanical dredging operations used in New England, where the dredge material is maintained in a compact, cohesive form and only the outer surfaces of the sediment are exposed to and mixed with the surrounding water, both during dredging and disposal operations. Lee, et al. (1975) postulate that this ratio may simulate the situation that would occur at a disposal site a short time after disposal has taken place.

The elutriate test estimates the release of contaminants during prevailing conditions of disposal operations; it does not measure release after the spoil has become redeposited. Lee, et al., proposed that the elutriate test should be performed under aerobic conditions since open-water disposal does not usually deplete the oxygen content of the water column. Release of manganese and iron into the water column results in formation of hydrous managanese oxides (HMO) and hydrous ferric oxides (HFO), which are efficient scavengers of other heavy metals and of organic substances. Ammonia was the major constituent released during the elutriate tests performed by Lee, et al.

In addition to the elutriate test, other extraction procedures have been employed to characterize the chemical reactivity and biological availability of certain pollutants. Chen, et al. (1976) performed sequential, selective chemical extractions of different types of sediment to determine concentrations of metals and organic substances in different fractions. The authigenic component, which included metals derived from natural and man-made sources, incorporated nodular hydrogenous, non-nodular hydrogenous, and biogenic fractions. The soluble and ion-exchangeable fractions for all types of sediment tested (sandy silt, silty sand, and silty clay) were less than 1% of the total sediment load and were deemed ecologically insignificant.

After long-term exposure of sediment to oxygenated sea water, the partitioning of metals in the nodular fraction showed that cadmium decreased, copper and lead increased slightly, iron and manganese increased, chromium and nickel showed no clear trend, and zinc showed slight decrease in clay sediment incubation but no change in sandy sediment. The non-nodular hydrogen fraction partitioning after long-term incubation resulted in increases in cadmium, chromium, copper, iron, nickel, and zinc, but no significant change in lead. Decreases in all metals except manganese in the biogenic fraction were discernible after incubation. This work also shows that there is a decrease in cadmium, iron and manganese in the lithogenous fraction after long-term exposure of the sediments to sea water, which differs from the traditional assumption that the lattice bound metals in the lithogenous fraction are unreactive.

Both the elutriate test and the sequential selective extraction procedure will give an upper limit of sorbed metal and organic concentrations. However, bioavailability of these constituents to benthic fauna will be more accurately determined by measuring trace metal and organic concentrations in available site organisms. Thus, the body burden of metals by different types of organisms may give an indication of the existing stress to the environment. However, Gordon, et al. (1972(SR-7) reported concentration ratios of zinc/copper for _Yoldia limatula_ and _Mulinia lateralis_ which were common to both dredge and dump sites at New Haven. No significant differences in ratios for the two sites were seen, even though dredge site sediment concentrations were twice that of disposal site sediments. Several problems arise in interpreting these data: the disposal site had been used previously; the bioavailability fractions of both the dredge and disposal site sediments are unknown; no control site organisms were used for comparison; and the selected organisms may have some degree of metal regulating ability. Thus, it is necessary to choose organisms that are both pollution-sensitive and others that are pollution-resistant.

The management of a disposal site requires accurate records of dumping. This history should describe all dumping events: the dates, the source and type of dredge spoil, the amount dumped, and any associated chemical or physical testing performed on the spoil or disposal site.

Baseline and post-dredging monitoring are necessary to determine any ecological impact in the area. The monitoring should be performed on a quarterly basis with one control station of sediment texture and depth similar to the disposal site.

Accurate bathymetric and current surveys and temperature, salinity and turbidity should be conducted prior to disposal operations. Containment effectiveness can be estimated from the depth, bottom currents and gross structure of the dump site. The maximum containment capability of the site should be calculated assuming more or less uniform dispersion of the spoil, and loading rates should be calculated based on predicted slumping and dispersal characteristics of the spoil. Follow-up bathymetric surveys will show whether the prior estimates of site capacity were accurate and whether the distribution of the spoil deposit is as predicted.

Any selection of sampling grid and frequency of sampling must consider the design of a measurement program. For coordination and comparison of data between various sampling periods for a single disposal site and between various disposal areas, it is recommended that a standardized methodology of sampling be established for physical, chemical and biological parameters. Navigational accuracy as noted by Saila, et al. (1975)(SR-1, SR-2) and Cook and Morton (1974)(SR-42), as well as sea state, limit the reliability of bathymetric profiles of spoil deposits. Accuracy of navigational as well as analytical instrumentation should be reported. Part of this standardization should include the specification of sample replication, reporting of methods used, limits of error for each measurement, and limit of detection for each method. In this way, coordination of data with state of the art methodology could resolve apparent differences between measurements.

The use of a box corer will allow visual inspection of the sediment strata, after which subsamples can be removed for grain size analysis. The remaining sample will be taken for benthos characterization. Finally, waters just above the spoil deposit should be analyzed for substances whose concentrations are likely to change as a result of spoil disposal, e.g. ammonia, dissolved oxygen, turbid suspensions, and trace metals. The results of chemical and biological analyses of sediment cores and of physical and chemical measurements of bottom waters, in conjunction with visual analysis of the bottom using a television camera, will provide an estimate of the changes in bottom characteristics and sediment-water column exchange rates.

The use of laboratory bioassays is controversial (see Part II). There is a case to evaluate the relative toxicity of the dredge material which would indicate how it will affect the fauna at a given site. It is clearly desirable to know before the fact what impact that material is likely to have. Such knowledge may also be used to determine the method of dumping, that is, a light covering over a broad area of a single point dumping with an attempt to cap the material to prevent escape of toxins.

The most effective way to evaluate impact is to do recolonization experiments at the site. As noted by Rhoads (1974)(SR-18, SR-43), recolonization may begin within as little as 2 months of the cessation of dumping. Recovery rates of benthic populations reported by various investigators indicate that recovery is most rapid when the spoil is physically similar to the sediments found in the area of the disposal site (Fisher and McCall, 1973)(SR-12). All evidence so far indicates that where disposal occurs in areas of compatible sediment type, recolonization of the target area begins within 4-13 months; furthermore, where disposal occurs and is then terminated, there is active recolonization and eventual equilibrium in the benthic structure of the target area.

Rhoads (1974)(SR-43) also observed nutrient exchange between sediment and pore water with various repopulation stages. By measuring sulfate and ammonia concentrations with depth of sediment at the dump site and comparing these profiles with those from a control area, the influence of community structure on nutrient turnover can be examined. Measurement of metal concentration factors in selected repopulation organisms will also give an estimate of the effect of the spoil on the benthic community. It is suggested that deposit feeders and sediment burrowing organisms be analyzed for this purpose. Concentrations of Zn and Cu were determined by Gordon, et al. (1972)(SR-7) for several benthic organisms in New Haven Harbor and Dump Site and no correlations were seen. However, no control site animals were tested. Emerson (1976) noted elevated levels of Cu, Fe, Pb, Zn, Cr, Ni and Cd in Capitella capitata subjected to elutriate water. Sensitive organisms normally present in the general area will probably be absent at the disposal site. However, recolonization is possible after cessation of dumping operations provided neither the sediment characteristics nor the bottom water quality is permanently altered. In fact, recolonization had commenced within 6-9 months after disposal operations ceased in studies conducted in Rhode Island and New Haven (Pratt, et al., SR-3; Rhoads, et al., SR-43).

Gannon and Beeton (1971) proposed procedures for determining benthos sediment selectivity and viability over 48 hours. This program could be extended to measure recolonization ability and the uptake of various contaminants (e.g. trace metals, PCB's) by several pollution-tolerant and pollution-sensitive benthic species. Such a program would have to be of long duration, perhaps six months, to allow for variable assimilation rates of different chemical forms. The effects of nutrient turnover by diffusion or burrowing organisms and any attendant increase in primary productivity could also be measured. Studies of this sort were performed in situ by Fisher and McCall (1973)(SR-12), but the costs of boat time and the possibility of losses due to storms, accidents, or vandalism make a laboratory-maintained system more feasible.

The potential effects of dumping on commercial and shellfish habitats are important economic and health considerations of disposal site management. The Food and Drug Administration has the responsibility of insuring the edibility of foodstuffs caught outside the 3-mile state jurisdiction as well as foodstuffs which travel across state lines. In this capacity they have the authority to close an area to commercial fishing of bottom fish and shellfish. The criteria which the FDA uses to determine closure are based on potential hazard to consumers resulting from the possibility of bioaccumulation of toxic substances in these organisms, and does not necessitate sampling. In the case of the Foul Area closure, the decision was based upon the disposal of materials containing such potentially toxic substances as mercury, cadmium, and phenols. Based on the documented presence of these substances in the spoil and the absence of short dumping, the FDA closed only the 2-mile diameter Foul Area to commercial fishery of shellfish and bottom-dwelling fish. The possibility of reopening the area to these commercial fisheries would necessitate cessation of further dumping of contaminated spoil, as well as documentation of acceptable levels of these substances in organisms taken from the Foul Area. The possibility of closure of the Boston Lightship Area by the FDA and the effect on the Massachusetts fishing industry must be considered.

FINAL SITE SELECTION AND MANAGEMENT PROGRAM FOR A MASSACHUSETTS BAY DISPOSAL SITE

The revised EPA Ocean Dumping Regulations of 11 January 1977 state that a best estimate is made of "those levels of pollutants which may be expected to cause environmental harm, to apply a safety factor, and to refuse to sanction dumping of wastes containing pollutants in these amounts unless there is no other environmentally acceptable alternative." For dredge spoil the limiting acceptable EPA requirements are:

(A) Trace contaminants of:
   1) mercury of less than 0.75 ppm or less than 50% greater than the concentration of mercury present in natural sediments of the disposal area
   2) cadmium of less than 0.6 ppm or less than 50% above natural background sediment levels
   3) organo-halogen constituent concentration of less than the known toxic level for marine organisms
   4) oil and grease of concentrations which do not produce a visible surface sheen when the spoil is diluted one part to 100 of receiving water

(B) The liquid phase of the elutriate test meets marine water quality criteria after initial mixing or is less than 1/100 of the toxic threshold concentration to marine organisms

(C) The suspended particulate and solid phases of the elutriate test will not cause unreasonable acute or chronic toxicity or other sublethal effects based on bioassay results using appropriate sensitive marine organisms.

The state regulatory agencies responsible for ocean disposal have differentiated between clean and dirty spoil on a case by case basis, but with no clear definition of either. Using the EPA criteria for ocean disposal to define clean and dirty spoil would clarify disposal limits and allow revision of these criteria to prevent permanent depression of benthic faunal diversity. Since the benthic community at the Foul Area is already depressed in diversity and population relative to the rest of Massachusetts Bay, the long-term effects of occasional disposal of dirty spoil should be small, but care must be taken to insure that the depressed area does not increase in size. Periodic benthic sampling at the disposal site will help to substantiate any significant population and/or diversity changes. It is reasonable to expect that as long as the EPA criteria are met and periodic evaluation of trace contaminants at the dump site in the water column and sediment show low levels, then the FDA would have no reason for closure.

Management of the present Marblehead Site must include capacity and loading rate limits, as well as a periodic assessment of physical, chemical and biological parameters to determine any environmental impact. The maximum load can be estimated on the basis of a cone about 50 feet high and encompassing the whole area of the disposal site, or a maximum volume of 13.5 million cubic yards. This number incorporates the assumption that the spoil stays in place with no compaction or erosion occurring. If one assumes a loading rate of 1 million cubic yards per year, this would mean that the site has reached capacity in 13 years. However, compaction can reduce the height of the spoil significantly, since the underlying fine-grained bottom sediments have been reworked to several centimeters by benthic organisms, and the spoil itself may be squeezed by pressure of successive loading. By implication, the maximum volume of 13.5 million cubic yards of dredged material dumped in the area may slump and compress as much as 20% over 13 years, depending on the material (the spoil pile at New Haven was observed to compact about 25% in 8 months), and an additional amount could be dumped to reach maximum capacity.

This cone height and resultant maximum volume is based in part on topography of the bottom in the area. This volume of spoil would have a repose angle approximately double that of the natural slope of the area and will keep the maximum height below the level of the ledge west of the site where the currents may change due to the abrupt contour change. The Marblehead site also has slow bottom currents with a residual flow. The maximum containment capability of the site is made assuming more or less uniform dispersion of the spoil, and loading rates assuming predicted dumping and dispersal characteristics of the spoil. We would recommend a follow-up bathymetric survey to show whether or not prior estimates of site capacity are accurate and whether distribution of spoil deposit is as predicted.

An additional measure of the repose of the spoil deposit and observation of the biological repopulation may be obtained from remote television survey of the site and surroundings after dumping. Characterization of the benthic community does require taking grab samples on a seasonal basis. All the evidence so far indicates that where disposal occurs in areas of compatible sediment types, recolonization of the target area begins within four to 13 months. Furthermore, where disposal occurs and is then terminated, there is active recolonization and eventual equilibrium in the benthic structure of the target area. Thus, in a disposal site such as the Marblehead Site, which has had prior study, benthic identification and evidence of recolonization are sufficient to demonstrate there is no adverse environmental impact of dumping. Laboratory bioassays would serve to demonstrate only acute effects of a material which may not occur when diluted in the environment. Bioaccumulation experiments may show incorporation and retention of a chemical, but have not been shown to affect reproductive success of an organism or affect higher trophic levels.

To accommodate spawning and migration patterns, the time of disposal operations should be between mid-March and July and between September and November. When feasible, dumping operations should be conducted during the winter.

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APPENDICES

A. Critique of N.E.D. Reports

B. Recommended Parameters of Dredging and Disposal Analysis

C. Contract Specifications

APPENDIX A

CRITIQUE OF N.E.D. REPORTS

INDEX OF N.E.D. REPORTS

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SR-41. Bohlen, W. F. and Devine, J. 1973. Bibliography of the disposal of dredge spoils in coastal waters (Univ. of Conn.).

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SR-44. Rhoads, D.C. 1975. XII. The use of bivalve death assemblages to recognize environmental change in Central Long Island Sound over the past 150 years (Yale Univ.).

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SR-47. JBF Scientific Corp. 1975. Test report on Thames River, Conn., sediments (JBF Scientific Corp.).

SR-48. JBF Scientific Corp. 1976. Test report on Fall River Dredged material disposal (JBF Scientific Corp.).

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Introduction

Baseline data of proposed disposal sites should be concerned with definition of the area both in terms of sediment and water quality. In order to accurately determine the physical, chemical and biological effects of dredging and disposal, quantitative measurements of both the dredging site and disposal area are necessary. These should include such measurable quantities as:

1) Sediment make-up
    a) grain size distribution
    b) % C or organic matter
    c) trace metals
    d) sulfide concentration
    e) hexane extractables, PCB's, hydrocarbons
    f) benthic population
2) Water column make-up
    a) suspended solids or turbidity profiles
    b) temperature profiles
    c) salinity profiles
    d) current profiles
    e) dissolved oxygen profiles
3) Bathymetry - Topographical profile of the bottom

Quantitative measurements of sediment and water should be determined seasonally to give an accurate characterization of the area under consideration. Most water quality parameters change with the season and the benthic population exhibits a normal mortality in the early winter, followed by a small stable wintering community until spring, when the population increases to the summer maximum. Sediment make-up and bathymetry may not change significantly over a year, but major events such as storms or spoil disposal necessitate at least biannual measurement. It is also useful to choose an area of the same general type as the proposed disposal site, in terms of depth, bottom characteristics and benthic population, as a control for comparison with the disposal site after spoil dumping.

It is important to have a broad data base with methods for each measurement chosen with care to provide the smallest reasonably expected analytical error. Since qualitative measurements are in general difficult to correlate with other measurements or with the same measurements from other areas, they should be limited to as few as possible. For example, descriptions of sediments as "smelly black ooze" would be more accurately described in terms of grain size distribution, % water content, % C or organic matter, sulfide concentration, and chemical and biological oxygen demand.

In a case such as bathymetry, where the topographical profile of the bottom before and after dumping can give an accurate determination of spoil disposition, a significant error in bottom topography can be propagated by a relatively small error in navigation. In the case of benthic population it is useful to count small and juvenile organisms in order to determine the extent of repopulation after spoil disposal. Thus, organisms should be sieved through a 0.5 mm screen which will retain a great many of these organisms. Replicate analyses are also useful since this gives some indication as to the sampling accuracy as well as the spatial distribution of organisms.

Seasonal currents, salinity, and temperature profiles are necessary to predict the best time to dump, the behavior of spoil deposition during dumping, and the long- and short-term effects of bottom currents on the spoil surface after dumping. The presence of a sharp pycnocline at certain seasons would increase the probability of producing a large turbid cloud along the boundary of the pycnocline. This cloud could then drift away from the disposal site and settle out over a great area. If spoil containment is desired, the presence of a pycnocline would prohibit dumping. Bottom currents affect spoil containment since large velocities will tend to scour the surface of the spoil until the grain size of the surface sediment is large enough or cohesive enough to withstand movement. It is also important to determine the relationship of tidal and non-tidal currents since these factors determine the direction resuspended spoil will travel and where it will resettle.

Determination of possible chemical, biological and physical effects of dredging and disposal prior to actual implementation of operations can be estimated with the assistance of an accurate data base. If the dredge spoil is sandy, there is little potential of introducing metals or organics to the disposal environment, and if disposal site currents are small spoil will remain in place.

If the spoil contains high percentages of silt and organics, there is the possibility of high sorption of metals which can be either released into the water column or sorbed on organic material. In either case the contaminants can become more readily bioavailable. The possibility of resuspension of the fines is determined by the current. These estimations can then be compared with measurements during or after dredging and disposal operations to determine the accuracy of predictions, to improve methods of dredging, and to refine disposal site selection criteria.

Literature Review

Reviews of the current literature are discussed in SR-38 and SR-41. SR-41 is a bibliography to supplement field studies of dredging and spoil disposal in Long Island Sound. Literature in the areas of physical, geological, chemical and biological oceanography, as well as general and miscellaneous literature regarding dredging and waste disposal dumping are included.

Report SR-38 reviews current literature on the interaction of heavy metals with sulfur compounds in aquatic sediments and dredged materials. This includes specific individual review of some of the current literature for Cd, Hg, Pb and a general review of Zn, Cu, Ni, and As as a group, with respect to complexation and dissolution of inorganic sulfides in the presence and absence of oxygen and of long chain alkyl thiols. Discussion of the possible addition of sulfide or alkyl thiols to dredged spoil dumped on landfills or possibly in aquatic dumps leads to the recommendation of controlled experiments to determine these effects. The literature survey and discussion is presented mainly from an engineering viewpoint. As a result, the chemistry of complexation and adsorption phenomena is very general.

Report SR-39 discusses the development of an interstitial sampler for the determination of trace metals in the interstitial waters of dredge spoil material. Possible contamination problems encountered in sampling and squeezing are discussed in detail. Contaminated ultra pure water, which had been allowed to stand in the squeezer for 10 minutes and then extracted through the apparatus at 15,000 psi pressure, was analyzed by ASV. The contaminated water contained 1.0 ppb Cu, 1.2 ppb Pb, and an undetectable amount of Cd. The concentrations of the Cu and Pb are higher than normally found in oceanic sediments except in highly polluted areas and the limit of detection for Cd is not given in the report, so one cannot say whether the squeezed water is significantly contaminated or not.

The report does suggest some areas of possible modification to reduce possible contamination, such as Teflon coating all non-porous parts. Another area of possible contamination is the filter paper. As mentioned in the report, filter paper must be carefully selected and tested to minimize contamination. Also discussed but not examined in the report is the problem of changes in metal speciation with changes in temperature and pressure. The literature review is extensive.

Studies of Rhode Island Sound, Buzzards Bay, and Block Island Sound

Eight reports in the series cover disposal sites in Rhode Island Sound and adjacent waters of Buzzards Bay and Block Island Sound. Some of these reports deal with physical data, some with biological data, and some with both. Various analyses of sediment makeup were determined in most reports (SR-1, SR-2, SR-3, SR-6, SR-28). Grain size analysis was routinely determined in all these reports, as was % organic matter. However, in SR-1 % organic matter was determined empirically from % C and in SR-6 no organic matter determinations were made. Trace metals were determined in only two reports, SR-3 and SR-28. Since trace metal concentration ratios may be important in spoil identification and since certain trace metals such as Hg, Pb, and Cd may be deleterious to deposit feeding benthic organisms, concentrations of trace metals in both the spoil and the disposal site sediments should be characterized. Hexane extractables were determined most cases, but PCB's and/or hydrocarbons, which might be a more effective indicator of pollution than median grain size or % organic matter, were only determined in report SR-28 although prior data for the study area is given in report SR-2.

Benthic analysis of the sediments was conducted following several sampling methods. Both the Peterson dredge (reports SR-1, SR-2) and the 0.1 m^2 Smith-McIntyre grab sampler (reports SR-2, SR-3, SR-6) were used for collection of triplicate samples for benthic population analyses and 0.75 mm screens were used to sieve the sediment rather than the 0.5 mm size recommended by

Sanders. As a result many small or juvenile species were lost, producing an inaccurate population assemblage.

All these reports give complete listings of organisms and population counts found at all stations which helps to compare data for these areas with other areas. However, little or no discussion of the precision and accuracy of the methods or the variance within the triplicate analyses is given in any of the reports. For example, an analysis of variance within the trpilicate samples to determine whether or not they are in fact replicates shows that although each station sampled in SR-3 is replicated at the 5% confidence level, those triplicate samples taken in SR-2 are not replicates at the 5% confidence level. As mentioned in SR-3 the differences between numbers of species from the two surveys "can be partially explained by more careful sorting of a larger number of samples (SR-3, p. 43). Thus, any comparative analysis between the two survey periods is limited by the accuracy of the SR-2 replication and the loss of small or juvenile species present at the station but not counted in the sample.

Analyses of the water column in reports SR-1, SR-3, SR-5, SR-6, SR-28, and SR-45 included turbidity measurements using transmissometers (except SR-28, which used a turbidimeter). In report SR-1 the field turbidity data was not presented since the data was not accurated, and in report SR-3 only one set of turbidity data is given due to instrument malfunctions. SR-6 gives turbidity and temperature cross-sectional maps of Browns Ledge proposed disposal site. As in the other reports, a turbid layer of bottom water is noted with an additional layer, usually of less turbidity, at midwater depth.

Few of the studies report temperature, salinity or dissolved oxygen profiles. Oxygen depletion may affect recovery of benthic organisms in the disposal site, as discussed in SR-2, and the presence of a halocline and/or thermocline will determine the accumulation of a turbid cloud at the gradient zone during and after dumping. Therefore, these factors should be examined to determine the temporal variations in dredge disposal.

Current studies, important in the analysis of spoil erosion, transportation, redeposition, and turbidity effects to the areas near the disposal site, were reported in SR-2, SR-6, and SR-42. Although the areas studied are well characterized for only a small portion of the year in these reports, they are in agreement with previous studies for the sites and repetition of the yearly cycle was not necessary.

Bathymetry measurements of the disposal site were taken in reports SR-1, SR-2, and SR-42. Accurate description of the bottom contours is necessary to determine deposition depth of the spoil and degree of spatial spreading of the spoil after dumping. The sea state is very important in this instance, since "an error of 1 foot depth measurement over 1 square mile dump area would represent approximately 1.03 x 10^6 cubic yards" (SR-2, p. 17). Navigational accuracy is also very important if size and distribution of the spoil loading is determined, as in report SR-1, SR-2. Bathymetry measurements of SR-42 report navigational accuracy.

Possible effects of spoil disposal are discussed in several reports. SR-1 indicates five factors for assessing the direct effects of turbidity as well as nine possibly detrimental indirect and two beneficial effects. Turbidity bioassay results of experiments performed with both dredge spoil and kaolin indicate that toxicity may be due to an unknown toxic component in the spoil rather than its turbidity. However, this toxic component was not characterized. Fish and other organisms swimming or trapped within a turbid layer have the ability to clear their gill membranes of particulate matter by a mechanism of mucous encasement. The organisms then eliminate these particles as pseudofeces.

The probability of recovery by various benthic organisms after burial by spoil is discussed in SR-2 and SR-3. The recovery from depths up to 21 cm of spoil burial and the effects of spoil anoxia on several types of sediment dwellers were studied. It has been shown that opportunists display a higher recovery from spoil burial and their tolerance to anoxia either by their ability to incur an oxygen debt or by lowering their metabolism aids in their recovery.

SR-4 is concerned with correlating possible turbidity effects of spoil disposal with fish populations. Analysis of the fish landings data shows no apparent relationship between recent commercial fish catch trends and dumping frequency.

Studies of Long Island Sound

Studies of Long Island Sound were performed to characterize the physical and biological environment of the central Sound area. Several investigators (SR-23, SR-24, SR-25, SR-19) used bottom and surface drifters to delineate the patterns of water movement, particularly in the area of the New Haven Dump Site. Bathymetry (SR-7,SR-8) and current studies (SR-7, SR-8, SR-19, SR-24) help to further characterize the central Sound and to verify a model of wind driven circulation (SR-24). Bathymetry in the New Haven Dump Site area over a yearly cycle shows about a 10% difference in spoil volume using data from SR-7, SR-8, and SR-19. This difference could be the result of navigational error, sea state, or fathometer error. Alternatively, it could be due to changes in the character of the spoil, e.g. water content decrease due to spoil compaction. Current data, compiled over an 18 month period at a height of 2 meters above the bottom, show a well-defined non-tidal component superimposed on the rotary tidal stream. It is important to determine the presence and direction of such a non-tidal drift since resuspended solids will be transported and deposited along this path.

Temperature, salinity, and dissolved oxygen profiles as shown in SR-7, SR-21, SR-22 indicate a predictable seasonal variation and the formation of a thermocline followed by a halocline in spring and summer. With isolation of the bottom waters by the presence of the pycnocline the dissolved oxygen concentration decreases progressively over the summer, but increases to a maximum in the winter with the disappearance of the pycnocline.

In situ suspended solid concentrations were analyzed in most reports using a transmissometer. In SR-21 and SR-22, a Secchi disk was used to measure transmissivity and suspended solids were measured by dry weight determinations of filtered water samples. The Secchi disk method is dependent upon the eye, sunlight angle and intensity, with an estimated error of 10-15%, and a transmissometer uses a white light source with an error of ~5% or better, depending on the path length of the instrument. SR-7, SR-8 and SR-19 use an optical transmissometer where the transmittance of white light through a 10 cm path of water is measured with about a 5% error noted in the standard calibration determination.

Turbidity was measured during dumping operations at New Haven Dump Site in SR-8 and SR-19 to characterize the concentration of the boundaries of the turbid cloud associated with the dumping operation. The data obtained from turbidity measurements during and after dumping show that point dumping is accomplished with only about 1% of the spoil carried a significant distance away from the dump point. Even though a cloud much higher than background is formed above the bottom, this cloud resettles within a radius of 120 meters of the point. The analysis of the dumping method and the observation of the spoil falling to the bottom very quickly as a density current rather than as individual particles is important in the long-term determinations of spoil erosion by bottom currents as well as short-term burial of benthic populations near the dump site.

Sediment characteristics of the central Sound include grain size analyses in SR-44 and SR-8. Shell fragments were only partially removed in SR-44 analyses so that comparisons of grain size with other parameters may be biased, particularly those comparisons of grain size with shell populations. Analyses of grain size in SR-8 appeared to be limited to sand/mud ratios. However, tests of bottom hardness in SR-7 give an estimate of the sand fraction and the non-cohesive character of the bottom.

Concentrations of copper and zinc in organisms found in New Haven Harbor spoil and at the New Haven Dump Site were compared in SR-7. Although no sediment analyses are given in the report, comparison of these two metals shows that concentrations in New Haven Harbor sediment are twice the New Haven Dump Site concentrations. However, the data presented for Cu and Zn in <u>Mulinia</u> and <u>Yoldia</u> do not reflect this concentration factor. The Cu/Zn ratios of spoil organisms are not significantly different from those of the dump site either. SR-7 also mentions the good correlation between Zn and % volatile solids, but no carbon data are given in the report, therefore no comparisons between these and other sites can be made.

No data for trace metals are given in SR-44 (the only other LIS report which even mentions trace metals), but the sample handling prior to metal analysis tends to bring the accuracy of any results into question. In this case, 2.5 cm increments of cores were sorted for removal of all shells before the remainder of material was preserved for trace metal analysis of Hg, Cu, Pb and Zn. The sorting process could introduce metal contamination to the sediment. No analyses of hexane extractables, PCB's, or hydrocarbons are given in any of these reports.

Benthic population analysis is very important in the determination of the character of the bottom and rate of decolonization of the dump site after spoil deposition. Characterization of the dredging and disposal site and control areas before and after dumping were carried out in SR-7, SR-9, SR-10, SR-11, SR-12, SR-13, SR-14, SR-15, SR-16, SR-17, SR-18, and SR-43. Samples were collected in all cases with a van Veen dredge, but in some cases an 0.147 m^2 size was used and in other cases (sometimes within the same report) an 0.0413 m^2 size or 0.025 m^2 size was used. In all cases the species population numbers were multiplied by the appropriate factor to equal numbers per one square meter. This technique cannot be used with impunity, however, particularly in areas of small-scale patchiness as noted near the New Haven Dump Site.

Many of the reports do not have a replicate sampling scheme, which further confounds the data presented. All the reports except SR-43 (which retained and counted organisms >300μ) used a 1 mm screen to sieve the organisms, so that only those organisms $\geq$1 mm are counted. The logic of using a 1 mm screen in terms of time and cost is noted but, as stated before, the loss of many small and juvenile organisms less than 1 mm produces seriously biased data for analysis of repopulation rates and the order of species introduction to the spoil sediment surface.

Hurlbert's rarefaction curves in SR-10, SR-11, SR-13, SR-14, SR-15, SR-17 and SR-18 in benthic analysis gives information concerning the sample size necessary to adequately describe the diversity of the sample. The use of these curves is an informative way to determine if stations have been undersampled.

Comparison of data presented in SR-10, SR-11, SR-13, SR-14, SR-15, SR-16, SR-17, SR-18, SR-20 with data from similar types of study areas is difficult since only molluscs were counted. SR-7 and SR-9 include all animals found in the sample, but again only those organisms >1 mm were counted. The problems incurred in comparing the areas studied in central Long Island Sound with other study areas result from inconsistency of benthic sampling, narrow limits on benthic population counting, and in one case (SR-12), lack of benthic data presentation.

The study reported in SR-12 presents an interesting attempt to analyze the processes of colonization and succession in the marine environment. The colonization rates of the various organisms shown in the figures presented and their survival rates give an indication of their relative competitive abilities and the rate of succession. However, no error analysis is presented of the replicate sampling. Thus, the relative accuracy of the relationships of the curves within the figures is not shown in the report. Since no benthic data are presented in the report statistical analyses for comparison with other studies is not possible.

Studies in Maine and New Hampshire

A study of the impact of dredging Belfast Harbor, Maine, and dumping the spoil off Isle au Haut (SR-33) evaluated material sampled at seven dredge area stations and five dump area stations. Ponar grab samples were sieved through a 1 mm screen for benthic organisms. Again, it should be noted that many juveniles and small organisms will not be counted.

In the discussion of spoil disposal the report states that "the data on total suspended solids indicate that the material dredged from Belfast Harbor tended to remain suspended at the surface and be carried away by surface currents." According to Bohlen, however, spoil of similar grain size is carried directly to the bottom by density current and the subsequent floating cloud at the surface (<10% of spoil) falls to the bottom at the rate of fall of silt and clay particles (~4 mm/sec). This is also seen by Saila, et al. (SR-1). The difference between the spoil fall in Belfast Harbor and the other reports may be due to 1) a large difference in % organics, 2) bottom current differences, 3) the presence of smaller size particles with relatively large cross sectional area, or 4) bathymetry errors. Figures and tables are not in the report although they are discussed in detail.

Report SR-34 studied the effects of dredging Rockland Harbor and spoil disposal in West Penobscot Bay, Maine. Analysis of water quality, sediment composition, and benthic populations at 10 stations were used to characterize dredge and disposal sites. Benthic population counts were limited to bivalves and polychaetes.

Although these organisms make up ~90% of the total organisms present, species diversity of the areas is incomplete. No sample replication was done for any station. The only immediate benthic effect of dredging and spoil disposal is a sharp decline in number of species and individuals followed by recolonization of motile predator-scavengers and deposit feeders such as Nephtys incisa and Nucula spp.

Monitoring the dredging effects on clam flats of Hampton Harbor, New Hampshire (SR-35) was accomplished by sampling 45 stations for clam samples and 7 stations for water quality analysis. The water quality analyses of total phosphorus, nitrate/nitrite ratio and iron were performed with kits which, in general, use a color reference chart. The kits used do allow for possible saltwater interferences. The use of a color chart usually results in larger errors than instrumental analysis does, but no error analysis is given. No apparent effects of dredging were seen from analysis of clams or water quality, but no analyses of dredge material are given to make any comparisons.

Studies in Boston Harbor and Massachusetts Bay

Delineation of any changes in water quality as a result of dredging in the Charles River estuary is reported in SR-29 and SR-30. Water quality analysis in both reports shows no significant differences in water quality as a result of dredging. Detection limits and error analysis for all tests are given. An increase in both zinc and cadmium concentrations in surface and bottom water occurred during dredging, but since no determination of the species of these metals in the water column was made, no conclusions can be made as to the subsequent effects of these metals in the marine environment. Analysis of speciation of various trace metals may be useful in the determination of the thermodynamics of these forms in the marine environment and the possible deleterious effects to either epibenthos or benthic fauna.

A baseline study of water quality, hydrography, and benthic population at the Boston Lightship Dumping Ground is reported in SR-27. Water quality analyses were made in duplicate, but no error analysis is given. Trace metals were semiquantitatively analyzed for lead, zinc, and mercury, but no methods or results for seawater or sediments are given in the report. Use of different types of grab samplers for different groups of stations is not conducive to general comparison over the whole area, since some samples are quantitative and some are not. The report states that triplicate benthic samples were taken but no species population counts are included in the report. Thus, analysis of sampling precision and comparison with data from other areas is not possible.

Report SR-40 discusses a sea floor television survey of the Foul Area conducted in conjuction with bathymetric records. No mention is made in the report of either Raydist errors in navigational accuracy or bathymetry errors, although the cruise report indicates Raydist calbiration. The video survey shows a large benthic population and evidence of numerous partially disintegrated concrete containers within the Foul Area.

The possibility of dredge spoil disposal affecting phytoplankton growth in the Foul Area is explored in report SR-31.

Neither methodology nor error limits are discussed in the reports for any of the quantitative or qualitative data. Identification of populations of planktonic algae is reported for the September sampling period but not for the August period. Neither set of data is quantified, although Skeletonema costatum is listed as "about 90%" of the September phytoplankton population. Discussion of the sampling periods in relation to a spoil dumping schedule is lacking.

The evaluation of the effects of channel dredging in the Annisquam River in report SR-32 shows no discernible differences between background and dredging effects. Light transmission, nutrients, phytoplankton levels and distribution were measured. Although no error analysis of the data is given, methods are annotated so errors can be determined, for comparison with other areas.

Report SR-36 studied the effects of laboratory controlled turbid conditions on phytoplankton, lobsters, ocean scallops, and mahogany quahogs. Turbidity effects are more pronounced in scallops than in quahogs, as evidenced by increased mucous cell proliferation and mucous secretion, but no physical damage to the gill surfaces of either was observed. Filtering rates in these animals were reduced dramatically by a turbidity of 0.5 gm/l. Skeletonema costatum, however, increased productivity over the range of 0-5 g/l. No error analysis of the scallop and quahog data is given, but the weight loss data are presented as a range rather than a single number so one can get an estimate of the error involved. Standard deviations are given for all phytoplankton data presented.

Spoil Erosion and Deposition Characteristics

Behavior of spoil sediments with respect to erosion, transportation, and deposition are discussed in SR-37, SR-46, SR-47 and SR-48. Threshold velocities and average sheer stresses were determined in SR-37 and SR-46. SR-47 and SR-48 discuss mounding characteristics as a function of percent moisture. The sediment tested in SR-37 and SR-48 was Fall River dredged material and the sediment tested in SR-46 and SR-47 was Thames River dredged material.

Thames River material has a higher threshold velocity, mounds at a lower moisture threshold, and contains one-half as much clay and three times as much sand and shell fragments as the Fall River material. All four of these reports present a clear, precise discussion of the contracted projects.

INDEX OF ANALYSES PERFORMED BY CONTRACT

Chemical Parameters

Nutrients:

Total Nitrogen in Sediments. SR-1, SR-3, SR-5, SR-33, SR-49.

Nitrate:

Water. SR-21, SR-22, SR-29, SR-30, SR-32, SR-35, SR-49.

Sediment. SR-32.

Nitrite:

Water. SR-21, SR-22, SR-27, SR-29, SR-30, SR-32, SR-35.

Sediment. SR-32.

Ammonia:

Water. SR-29, SR-30, SR-32, SR-43, SR-49.

Sediment. SR-32.

Sulfate:

Water. SR-43.

Sediment.

Phosphate:

Water. SR-21, SR-22, SR-27, SR-29, SR-30, SR-32, SR-35, SR-43, SR-49.

Sediment. SR-32.

Dissolved Oxygen: SR-21, SR-27, SR-28, SR-29, SR-30, SR-33, SR-49.

C.O.D.: SR-3, SR-49.

B.O.D.: SR-21, SR-22, SR-27, SR-49.

Trace Metals:

Water. SR-27, SR-28, SR-29, SR-30, SR-35, SR-36, SR-38, SR-39.

Sediment. SR-3, SR-7, SR-27, SR-28, SR-30, SR-33, SR-38, SR-39, SR-44, SR-49.

Organisms. SR-7.

Organics in Sediments:

Volatile solids. SR-1, SR-2, SR-3, SR-7, SR-28, SR-30, SR-33, SR-37, SR-46, SR-49.

% carbon. SR-1, SR-2, SR-5, SR-33.

PCB's. SR-2, SR-28.

Hydrocarbons. SR-1, SR-2, SR-3, SR-27, SR-28, SR-49.

<u>Biological Parameters</u>

Benthic population counts. SR-2, SR-3, SR-6, SR-7, SR-9, SR-10, SR-11, SR-12, SR-13, SR-14, SR-15, SR-16, SR-17, SR-18, SR-20, SR-27*, SR-34, SR-35, SR-43, SR-44, SR-45, SR-49.

Replication. SR-2, SR-3, SR-6, SR-13, SR-14, SR-15, SR-17, SR-18, SR-27*, SR-44, SR-45, SR-49.

Statistical analyses. SR-2, SR-3, SR-6, SR-9, SR-10, SR-11, SR-12, SR-13, SR-14, SR-15, SR-16, SR-17, SR-18, SR-34, SR-49.

Bioassays. SR-1, SR-2, SR-3, SR-36.

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Fishery survey. SR-2, SR-3, SR-4, SR-49.

Dry weight biomass. SR-3, SR-7, SR-9, SR-10, SR-11, SR-13, SR-14, SR-15, SR-17, SR-18, SR-20, SR-36.

Modelling. SR-16, SR-24, SR-44, SR-49.

<u>Literature Review.</u> SR-38, SR-41, SR-49.

*Partial replication of one station with population counts indicated by frequency occurrence rather than exact numbers.

APPENDIX B

RECOMMENDED PARAMETERS OF DREDGING AND DISPOSAL ANALYSES

Parameter	Method	Precision
Bathymetry	Navigation by triangulation coordinated with fathometer trace.	Bottom contour ± 0-5 feet
Currents	Recording vector and speed current meter.	<± 0-1 knot
Temperature	Calibrated thermometer.	± 0.05° C
pH	Calibrated glass electrode.	± 0.05
Salinity	Refractometer. Chloride titrimatric, EPA Conductivity, EPA	± 2% RSD* ± 3% RSD ± 7% RSD
Turbidity	Transmissometer, 10 cm pathlength Nephelometer, EPA	± 5% RSD ± 3% RSD
Ammonia	Selective ion electrode, EPA. Phenate spectrophotometric, EPA.	± 3% RSD ± 14% RSD
Nitrate	Cd-reduction, diazotization spectrophotometric, EPA.	± 4% RSD
Nitrite	Diazotization spectrophotometric, EPA	± 4% RSD
Total Kjeldahl N	Distillation, selective ion electrode, EPA	± 5% RSD
Phosphate, total	Persulfate digestion, single reagent, spectrophotometric, EPA	± 12% RSD
Orthophosphate	Single reagent, spectrophotometric, EPA	± 6% RSD
Dissolved oxygen	Modified Winkler titration	± 2% RSD
Chemical oxygen demand	Titrimetric, EPA	± 10% RSD
Biochemical oxygen demand	5-day dark incubation, EPA	± 15% RSD
Trace metals	Atomic absorption spectroscopy; plasma emission spectroscopy (EPA)	A

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* RSD = Relative Standard Deviation

Parameter	Method	Precision
Volatile solids	Weight loss by ignition at 550° C, EPA	6% RSD
Total organic carbon	Catalytic or wet chemical oxidation to CO_2 measured by IR detector	10% RSD
PCB's	Gas chromatography	B
Hydrocarbons	Gas chromatography	B

A = Analyses should be performed to determine error for the specific metal in question. Since the concentration of some metals in water or sediment is small, methodology should be used which has a detection limit considerably lower than that concentration expected for a particular metal.

B = Since concentrations may be small, preconcentration of constituents to at least twice the determined detection limit of the instrument should be performed and error analysis determined.

Proposed Disposal Site Monitoring Scheme

Baseline Studies - Intensive monitoring program of disposal site and control site

Dump

Intensive Monitoring

Any adverse effects noted in conjunction with bioassay

Yes — Maintain intensive monitoring

No — Spot check monitoring

Intensive Monitoring Program would include:

A) Physical Parameters - bathymetry, currents, temperature, turbidity and salinity, including seasonal profiles of all variables.

B) Chemical Parameters - nutrients (nitrate, nitrite, ammonia, organic nitrogen), metals (Cu, Cd, Hg, Pb, Ni, Zn) and xenobiotics from the water column, interstitial water, and sediments; and metals and xenobiotics from benthic organisms.

C) Biological Parameters - population counts of macro- and meiofauna, changes as a function of dredge spoil dumping and documentation of biological recovery of the disposal area and neighboring areas in relation to control area.

Spot Check Monitoring Program would include:

A) Television observation of the bottom in conjunction with box cores which could be used for all chemical and biological analyses as well as for visual inspection of stratification of the sediment; annually following dumping termination, seasonally following dumping suspension.

B) Chemical parameters - Ammonia, dissolved oxygen, trace metals and xenobiotics from the interstitial water and sediments; metals and xenobiotics from benthic organisms.

C) Biological parameters - Subsamples of box cores for population counts to correlate with television survey estimates in documentation of biological recovery of the disposal area and neighboring areas in relation to control area.

D) Bioassay - Spoil sample and control with recolonization monitored to evaluate nutrient cycling, energy transfer, and concentration factors of benthic populations for metals and xenobiotics.

APPENDIX C

CONTRACT SPECIFICATIONS

1. PROJECT

a. Authority - The authority for this project is derived from the River and Harbor Act of 1970.

b. Line Item Designation - The contemplated work is in connection with:

Line Item	Description
1	Critique and Proposal for the Management of Dredged Material in Massachusetts Bay Waters

The foregoing line item designation of the work is a departmental method of identifying specific work items. The assigned line item is arbitrary.

2. PROJECT DESCRIPTION

The work included in the project to be accomplished under this contract comprises a synopsis and critique of various in-hours studies related to dredged material disposal and development of criteria for a regional dumping management plan. The work shall involve the furnishing of all necessary scientific personnel and equipment, including vessels and supplies, except as specifically otherwise noted in this Appendix "A".

3. COORDINATION AND PROSECUTION OF WORK

a. All requests made by other agencies shall be referred to the Project Engineer for action by the Contracting Officer.

b. All work shall be in accordance with the instructions furnished by the Contracting Officer.

c. All plans, documents and other data furnished by the Government, as designated by the Contracting Officer, shall be returned to the Contracting Officer within 30 calendar days after the completion of the work to be accomplished hereunder.

d. The Contractor shall make any corrections to work accomplished hereunder as may be necessary because of errors and omissions.

e. The Contractor shall make, at his own expense, all visits to the New England Division Office as may be required to accomplish the work under the contract.

f. The Contractor's fee shall include the cost of all special studies, consultant services and laboratory work required to accomplish the work under the contract, except as may be otherwise specifically provided in the contract.

g. The exposure data required under paragraph (b) of the contract article titled "Accident Prevention" shall be reported monthly to the Project Engineer. These data comprise the total man-hours of work actually performed in the field during the preceding month. This report shall reach the Project Engineer by the 18th day of each month.

4. CONTRACTOR SERVICES

The Contractor shall perform all work required to accomplish the intent of this contract and as part of such work shall perform the following services:

a. General: The work to be performed under this contract consists of office, laboratory and field work necessary for the production of an interim report and a final report. The orientation of these reports is to be directed towards the ultimate achievement of an EIS and a management scheme to regulate the ocean dumping grounds of the Corps of Engineers with specific emphasis on the grounds that lie in Massachusetts Bay.

b. Controls: Observations, collection and equipment shall be in accordance with U.S. Navy Publication H.O. 607 - Instruction Manual for Obtaining Oceanographic Data, or in an equal or superior manner, approved by Contracting Officer. Likewise, laboratory procedures shall be at least up to the levels of Standard Methods of APHA and the "Chemistry Laboratory Manual, Bottom Sediments" of the National Environmental Protection Agency.

c. Synopsis and Critique: The NED has sponsored and conducted in-house, during the past several years, various studies related to the ocean dumping of dredged materials. The studies have been supplemented by four "ocean disposal conferences", the proceedings of which have been transcribed. Related study information also is provided in the form of reports prepared by the University of Texas at Dallas under contract to WES DMRP. The contractor shall synthesize, analyze, and criticize in a constructive manner, this entire body of information, including any other relevant information within his own cognizance, and integrate the materials in such a way as to result in an analytical report (hereinafter referred to as "interim report"), which will reflect to the highest degree the state of knowledge that exists in this heretofore undeveloped area of scientific expertise.

d. Criteria and Management Plan for Regional Dumping: The procedure followed at present by the Commonwealth of Massachusetts with respect to the ocean dumping of dredged materials is that "polluted" materials are scowed to the "foul area," about 22 miles east of Boston, and relatively "clean" materials go to the "Boston Light" dumping ground, approximately 17 miles east of the port. Commonwealth regulatory officials would like to establish criteria to apply to determine which material should be relegated to the "foul area" and which can be permitted to be dumped with environmental impunity at the "Boston Light" grounds. The "final report" shall include proposed criteria for recommended adoption by the state and, in addition, a proposed management scheme that will encompass a philosophy and means of the management of disposal of dredged materials for those areas in which it is impractical to use the "Boston Light" and "foul area" grounds, such instances to include consideration of the disposal in sanctuary areas as defined by Commonwealth Law. The Contractor is expected to coordinate closely the development of criteria and the management plan with appropriate state officials as the work progresses. The management plan shall take into consideration short-term and long-term stochastic effects.

e. Field Investigations and Laboratory Experimentation: It is anticipated that the contractor will conduct such field surveys and laboratory experiments necessary to supplement and/or verify the development of dumping criteria. The scope of these activities will be determined by the Contractor's chief scientist based on his requirements for satisfactory completion of the report.

f. Reports: Two reports are required: an "interim" report, to be submitted six months from the contract date, and a "final" report, due at the conclusion of the contract. The interim report will consist of a synopsis and critique of existing study information concerning the ocean dumping of dredge material. It will include a bibliography describing all of the source information for the critique. The final report will rationalize and describe in sufficient detail for practical adoption criteria and a management plan for the regional dumping at sea of dredged materials. The rationale contained in both reports will be oriented towards the ultimate development of a blanket environmental impact statement that will cover all of the Massachusetts Bay dredged material ocean disposal activities.